

Attachment - 4

Student Conducted Studies of Catalytic Electrode Surfaces for Fuel Cell Applications
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"The ideal vehicle is the electric."

"The electric [vehicle] never could be made commercial with the lead-sulphuric acid battery, which, while based on a unique reaction in chemistry, and very beautiful in theory, does not, and never can, fit in to meet the commercial requirements of fool-proofness"
-Thomas A. Edison, 1911

Internal Combustion Engines

- Fueled by combustion of octane:
 $2 \text{C}_8\text{H}_{18} + 25 \text{O}_2 \rightarrow 16 \text{CO}_2 + 18 \text{H}_2\text{O}$
- CO_2 is an undesirable by-product
- Most of the energy is wasted as heat

Current Batteries

- Heavy
- Bulky
- Acceleration is poor
- Often contain undesirable heavy metals
 - Lead, Cadmium
- Take time to recharge

Hybrid Electric Vehicles

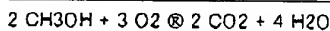
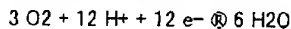
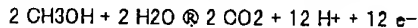
- Combine combustion and electric motors
- Combustion engine provides power
- Electric motor is used for cruising
- Batteries may be recharged during braking
- Fuel Cells

Fuel Cells

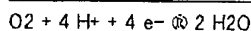
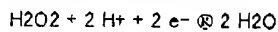
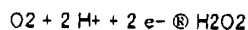
- Use a variety of fuels
 - Hydrogen, H_2
 - Methanol, CH_3OH
- Can be refueled at a filling station
- Directly convert chemical to electrical energy
 - More efficient
 - Lower emissions per mile traveled

Fuel Cell Chemistry

Process is separated into half reactions:



Oxygen Reduction



H₂O₂ Reduction on Gold

Recorded in

0.5 M HClO₄

+ x M Bi³⁺

+ y M H₂O₂

Underpotential Deposition (UPD)

- $\text{Bi}^{3+}(\text{aq}) + 3 \text{e}^- \rightarrow \text{Bi}(\text{s})$
- First layer of Bi deposits more easily than subsequent layers
- Bi-Au bond is stronger than Bi-Bi bond
- First layer deposits in multiple steps

Bi reduction on Gold

Bismuth on Gold at 0.3 V

Bismuth on Gold at 0.4 V

Possible Catalysis Mechanism

Why does the open structure form?

- Hydroxide, OH⁻, sticks to the surface in the catalytic region
- OH⁻ is omnipresent in water
- We need a solvent that will allow us to form the Bi layer without water

Ionic Liquids

- Combine organic cation with an inorganic anion
- Liquids at room temperature
- Highly conductive

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BPC/AlCl₃

- Butylpyridinium chloride (BPC)
- Aluminum chloride

Bismuth Reduction in BPC/AlCl₃

Bi Deposition in H₂O and BPC

Charge Passed During Deposition

Conclusions

- Bi UPD can be observed in ionic liquid solvents
 - Hydroxide is not necessary for Bi deposition in multiple steps
 - Undergraduate and High School students can work together productively on a research project
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Questions for the Future

- Does Bi form the same structures in BPC as in water?
 - Will Bi on Au catalyze H₂O₂ reduction in BPC?
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Acknowledgements

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Rob Doe

Ping Tai

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Direct Methanol Fuel Cell

Operation:

- liquid feed, no pressure
- fuel: 3% MeOH in H₂O

Reactions:



Challenges:

- MeOH permeation thru electrolyte
- catalyst performance: Pt-Ru 8 mg/cm²

